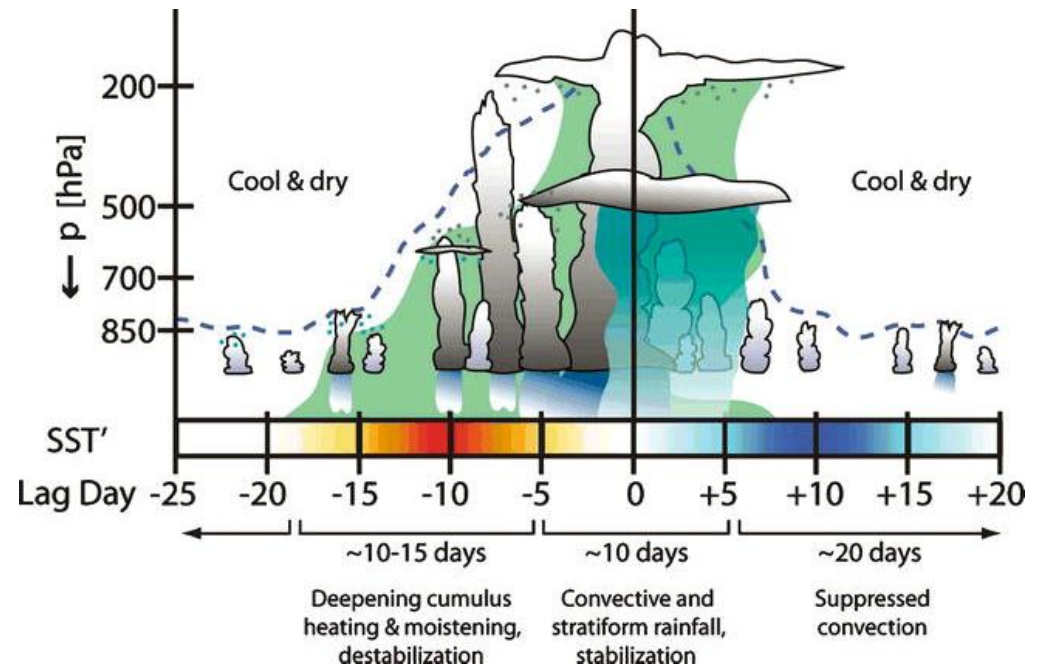
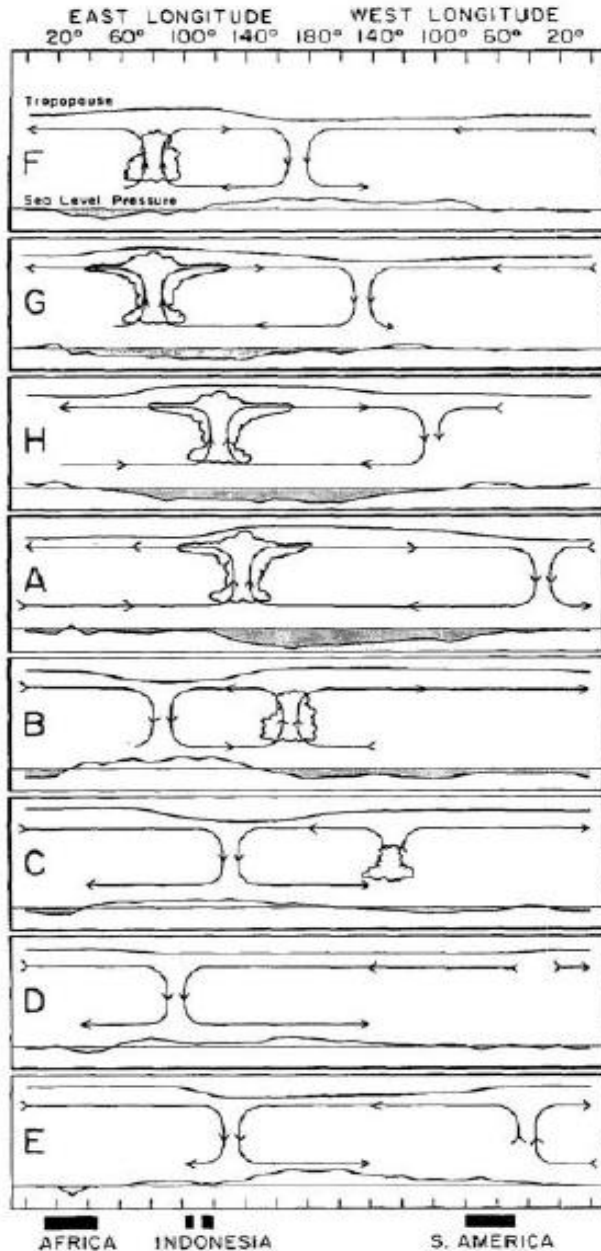


Small vs. Large Convective Cloud Objects from CERES Aqua Observations: Where are the Intraseasonal Variation Signals:

Kuan-Man Xu
NASA Langley Research Center
Hampton, VA, USA

What are the relative roles of small and large convective cloud clusters during the Madden-Julian Oscillation (MJO) life cycle?

- How are the size distributions of convective cloud clusters changed during the MJO life cycle?
- How much are physical properties changed from one MJO phase to another?



Convective cloud clusters are organized into various sizes and highly variables during the MJO life cycle.

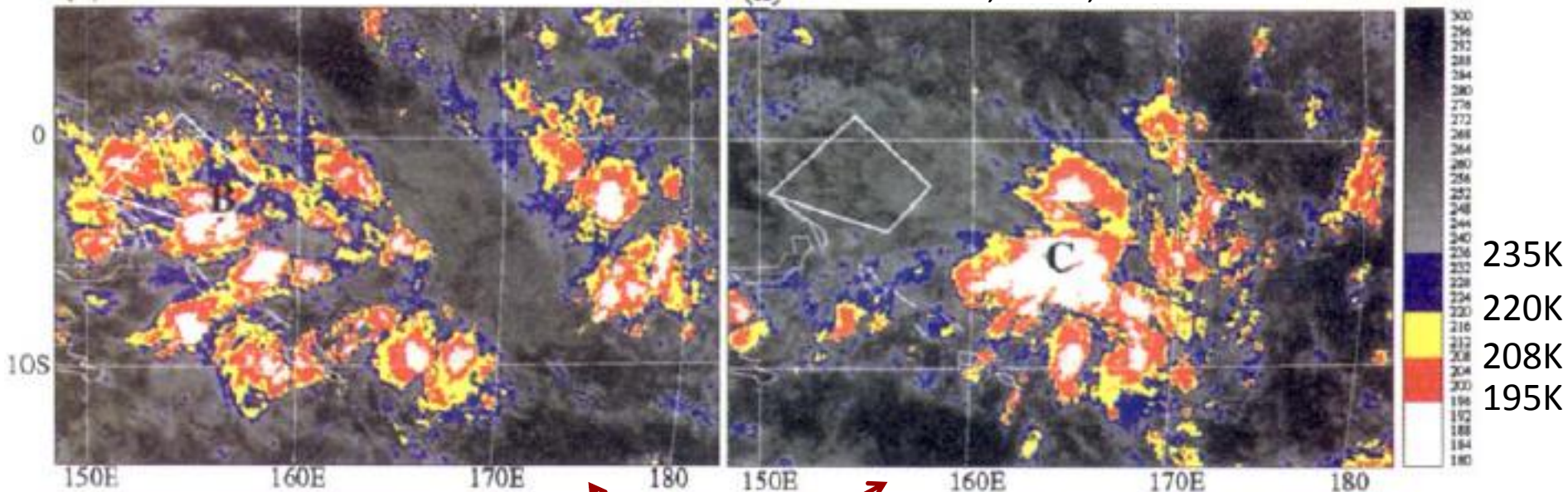
Our hypothesis is that the largest ones contribute to the intraseasonal variations while the small ones are just the background noises.

Tropical cloud cluster sizes (Chen et al. 1996)

3

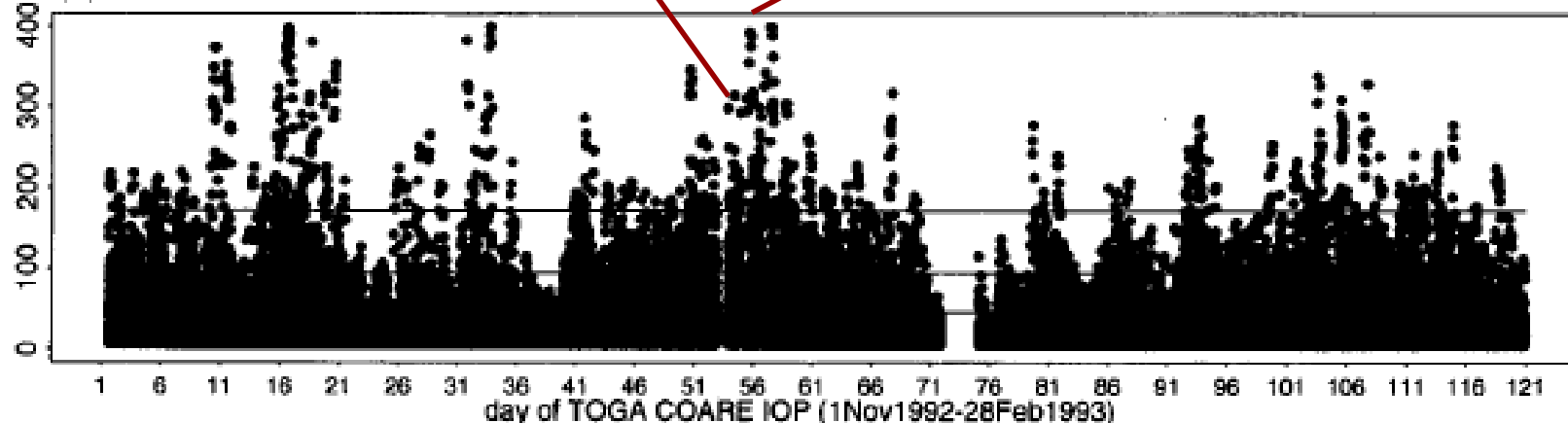
Dec 24, 1992, 11:30 GMT

Dec 25, 1992, 11:30 GMT



Equiv. cluster radius (km)

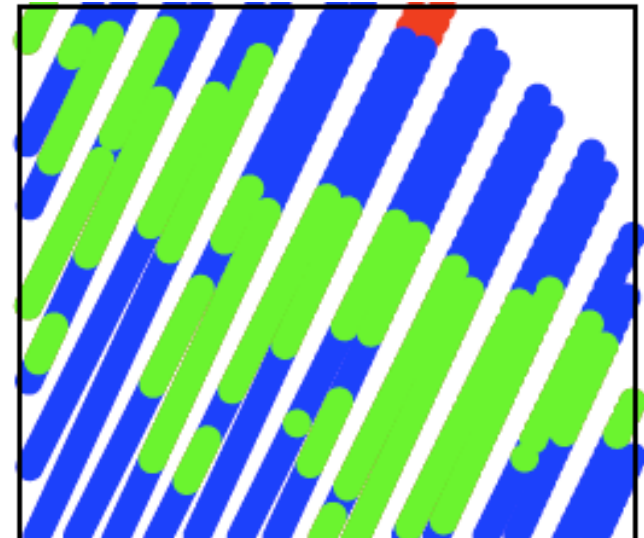
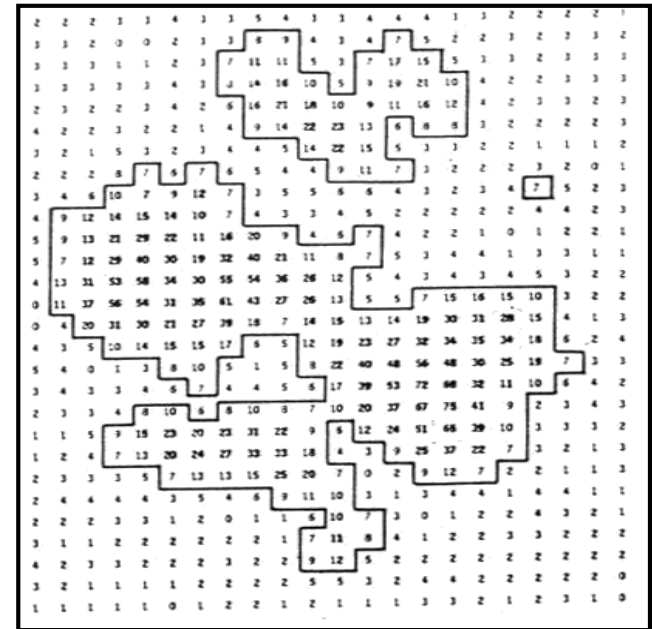
(c) LSA (147-180E, 10S-10N) cloud clusters with brightness Temp. < 208 K



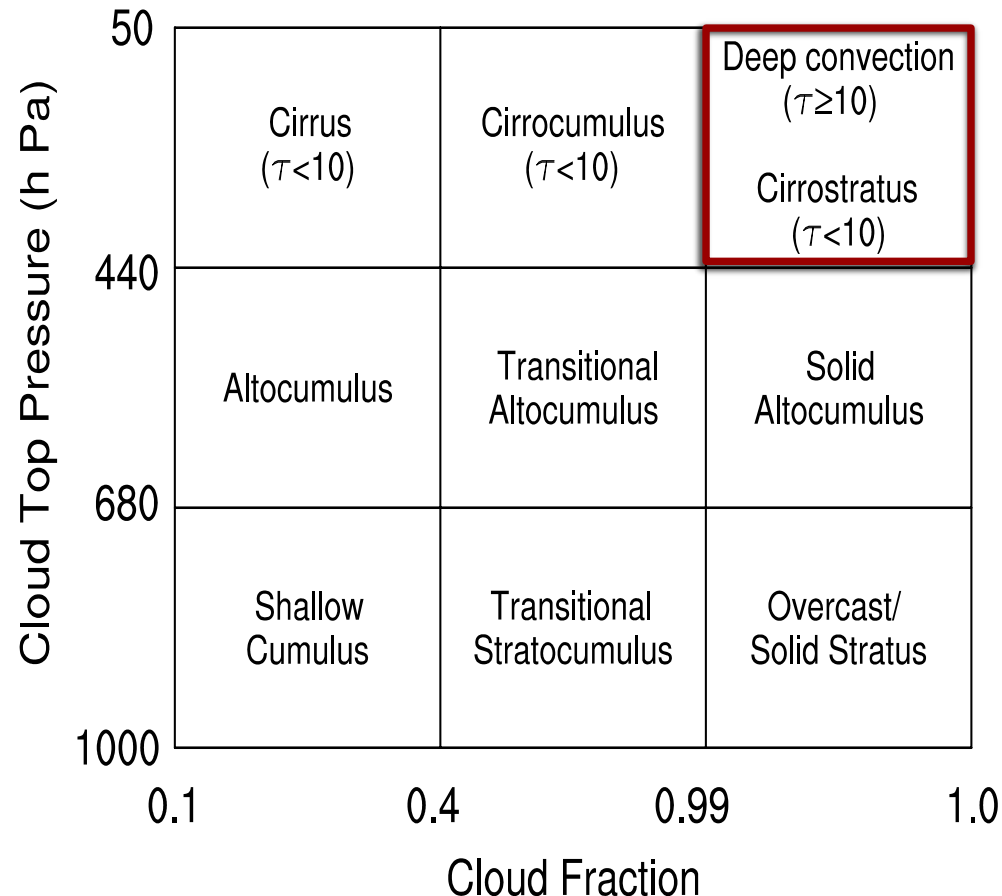
Wielick and Welch (1986)

Xu *et al.* (2005, 2007, 2008); CERES level-2 data

- A contiguous patch of cloudy regions with a single dominant cloud-system type; no mixture of different cloud-system types
- The shape and size of a cloud object is determined by
 - the satellite footprint data
 - the footprint selection criteria
- The identified cloud objects of different types can be further categorized by the large-scale atmospheric conditions based on the Madden-Julian Oscillation (MJO) index in this study

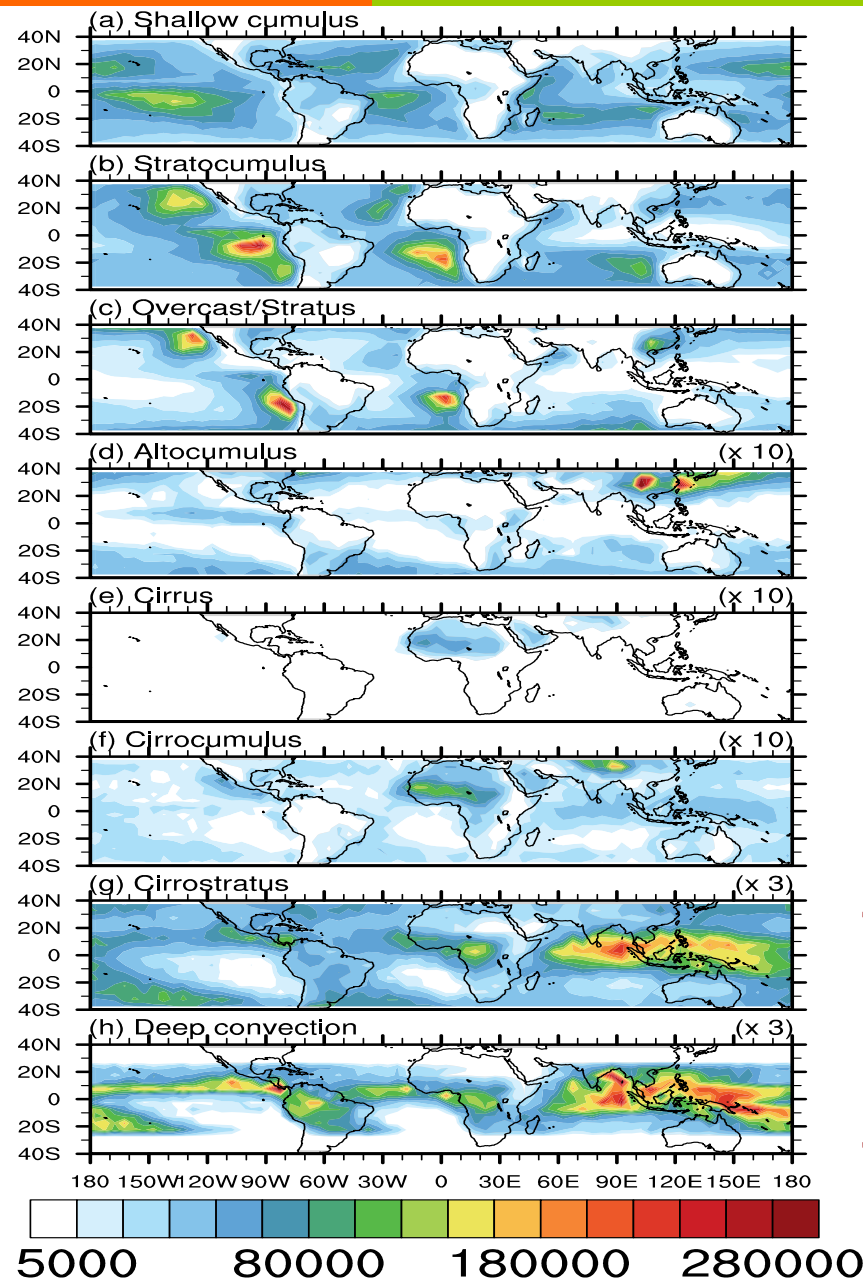


Cloud Regime Classification for the Cloud Object Analysis



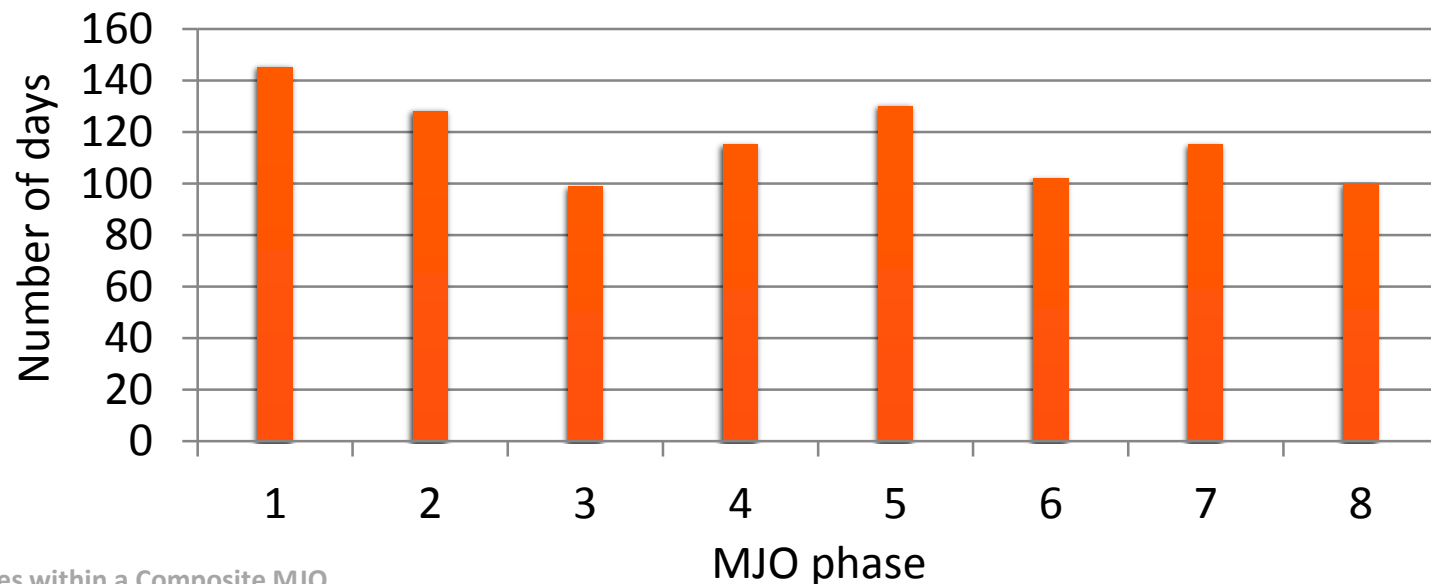
Xu, K.-M., *et al.* (2015): Cloud Object Analysis of CERES Aqua Observations of Tropical and Subtropical Cloud Regimes. Part I: Four-year Climatology. *J. Climate*, in press.

- ✓ Cu, Sc and Oc cloud types occur at preferred locations
 - ✓ Cumulus over open ocean
 - ✓ Overcast near the coasts
 - ✓ Rarely over ITCZ regions or land
-
- ✓ Only cirrostratus ($\tau < 10$; overcast) is abundant
 - ✓ They are associated with deep convection
-
- ✓ Deep convection occurs over ITCZ and SPCZ; and less frequently over land



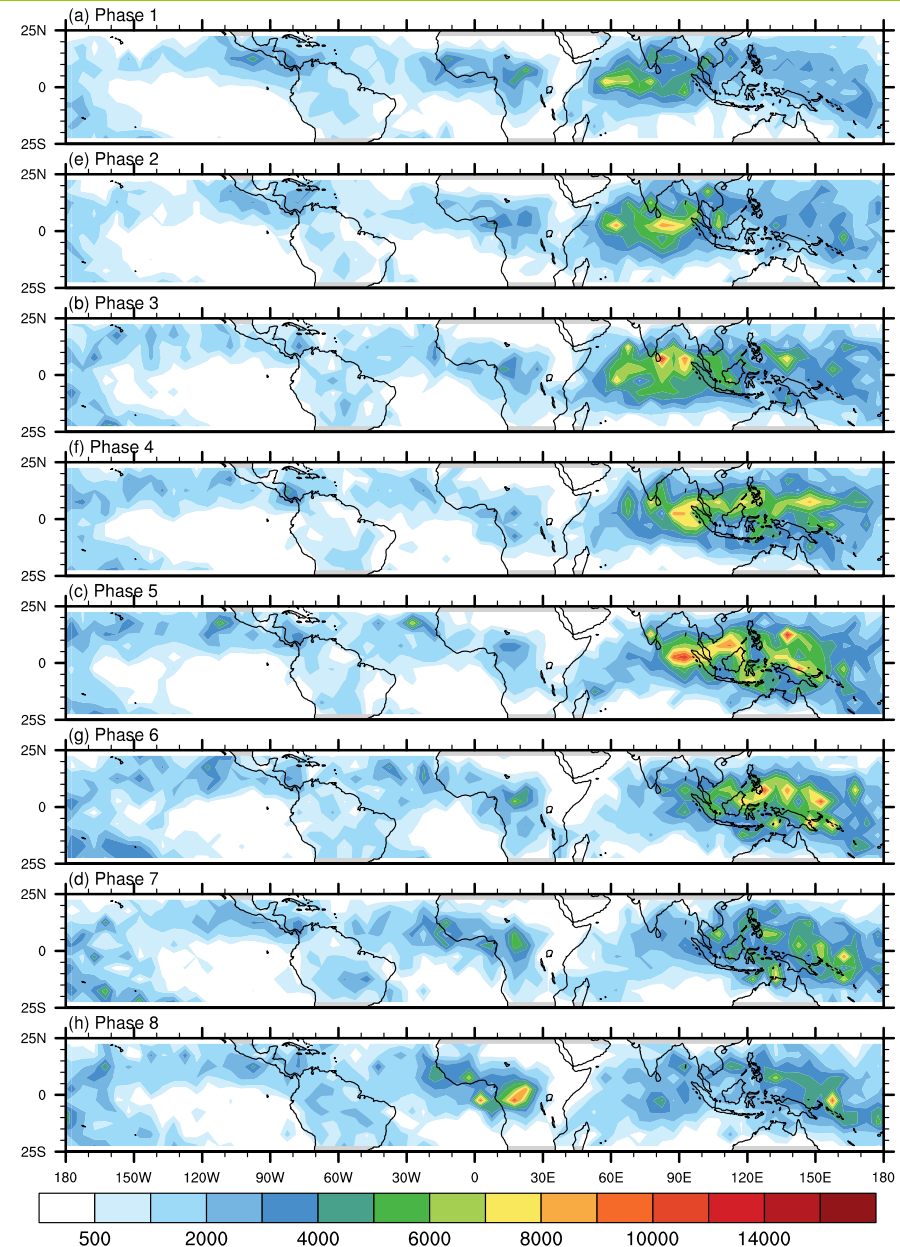
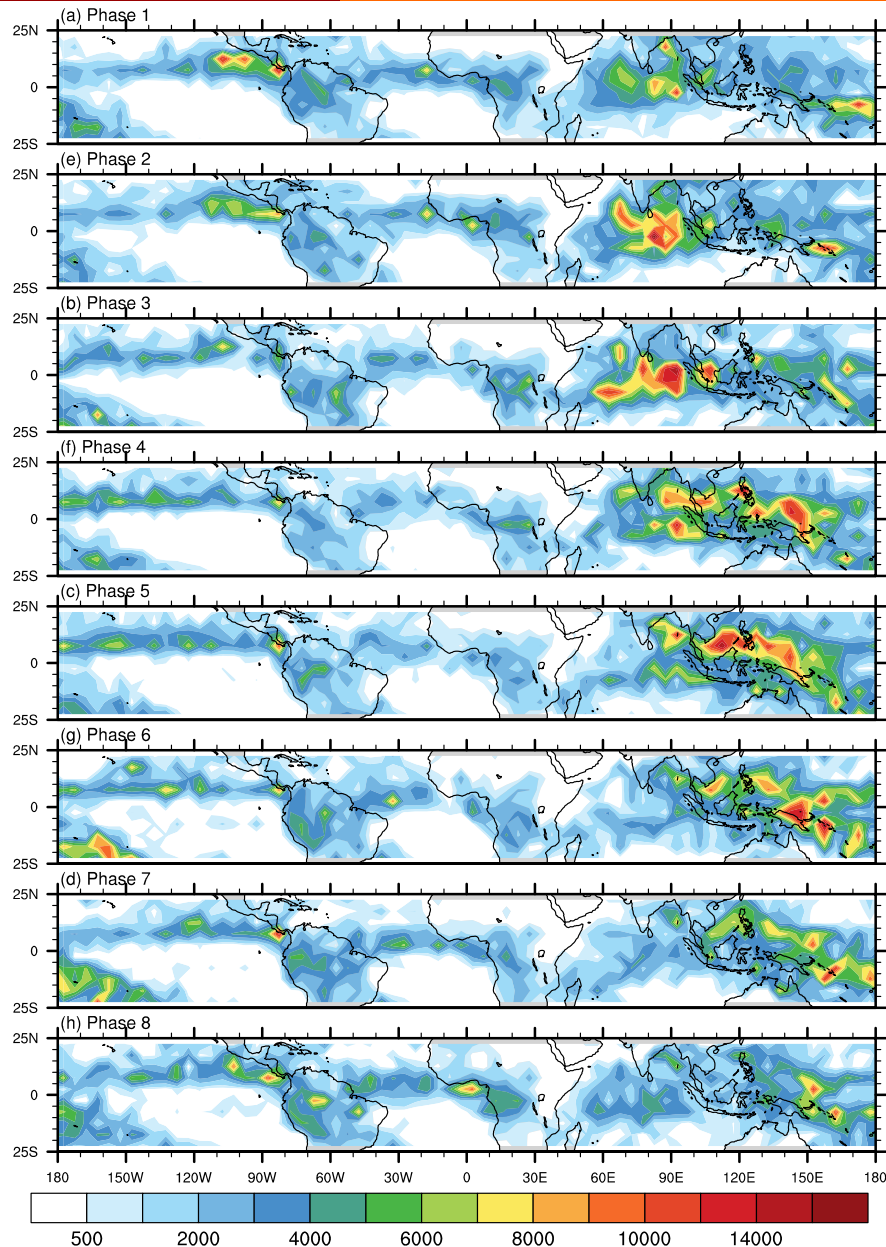
} This Study

- ✧ Clouds and the Earth's Radiant Energy System (**CERES**) Single Scanner Footprints (SSF)
 1. Four year data on Aqua: July 2006 – June 2010
 2. **25°S to 25°N latitudinal band only**
 3. Deep convective and cirrostratus types only
- ✧ Real-time Multivariate MJO (RMM) index (combined EOFs of u850, u200 and OLR)
 1. The days with amplitudes of $(\text{RMM1}^2 + \text{RMM2}^2)^{1/2} > 1$, **active MJO days**, are used; 934 (out of 1461) days
 2. All frequencies of occurrence shown later **are normalized by 116.75 days**

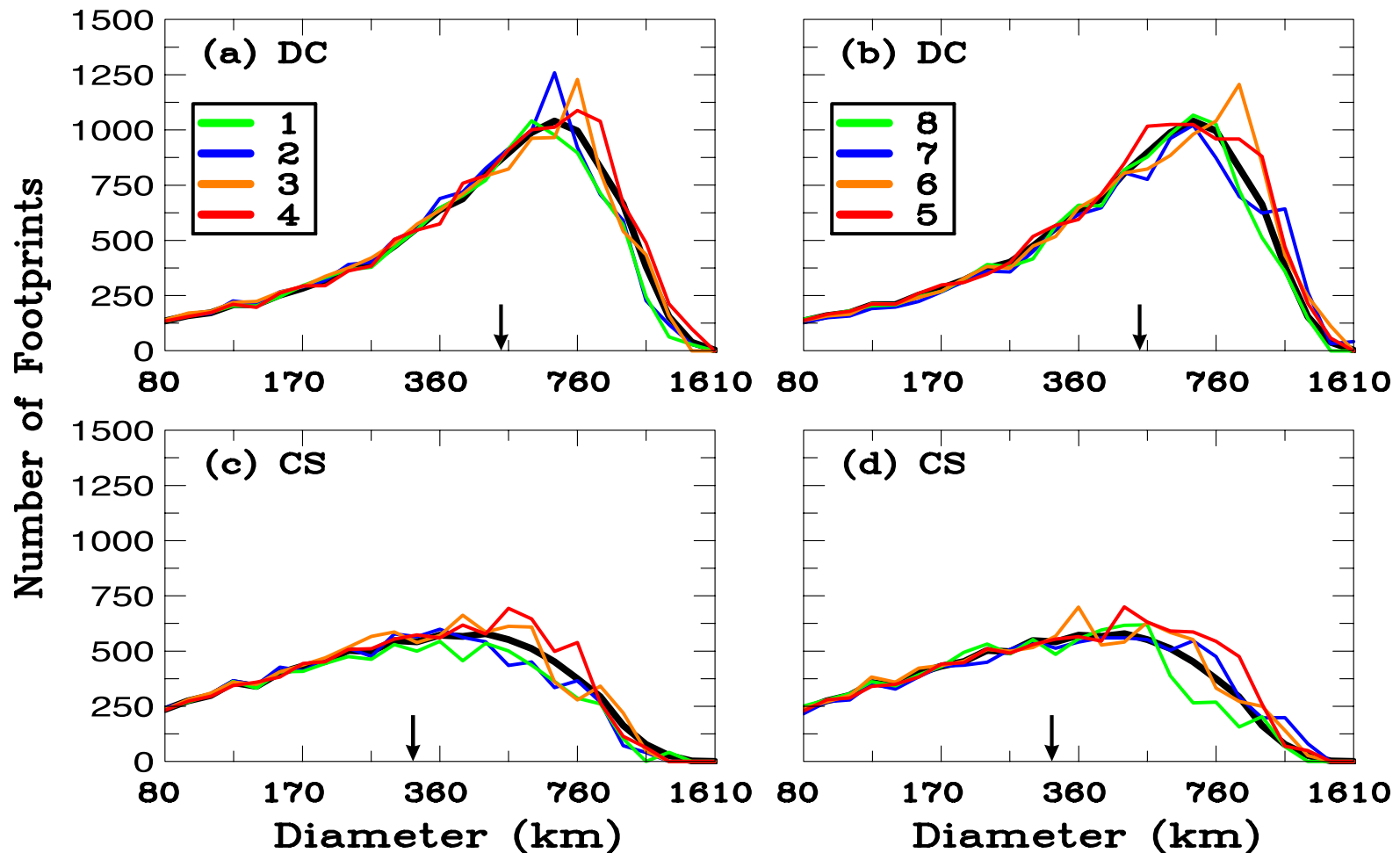


Areal coverage of DC and cirrostratus cloud objects

8

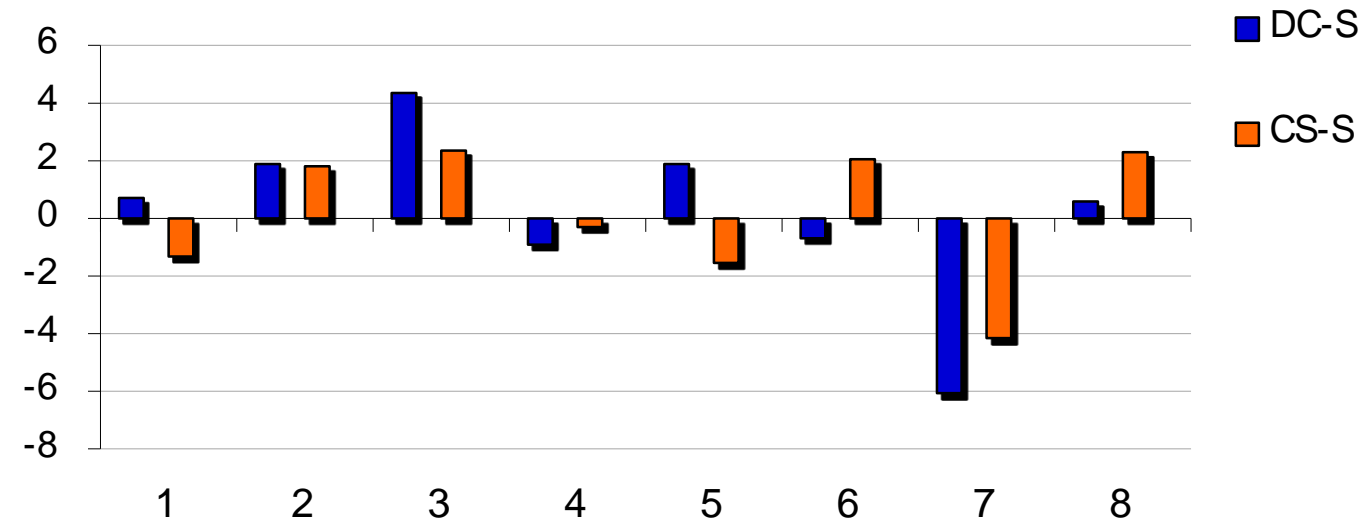


Cloud Run: www.ta.ac.jp 2016

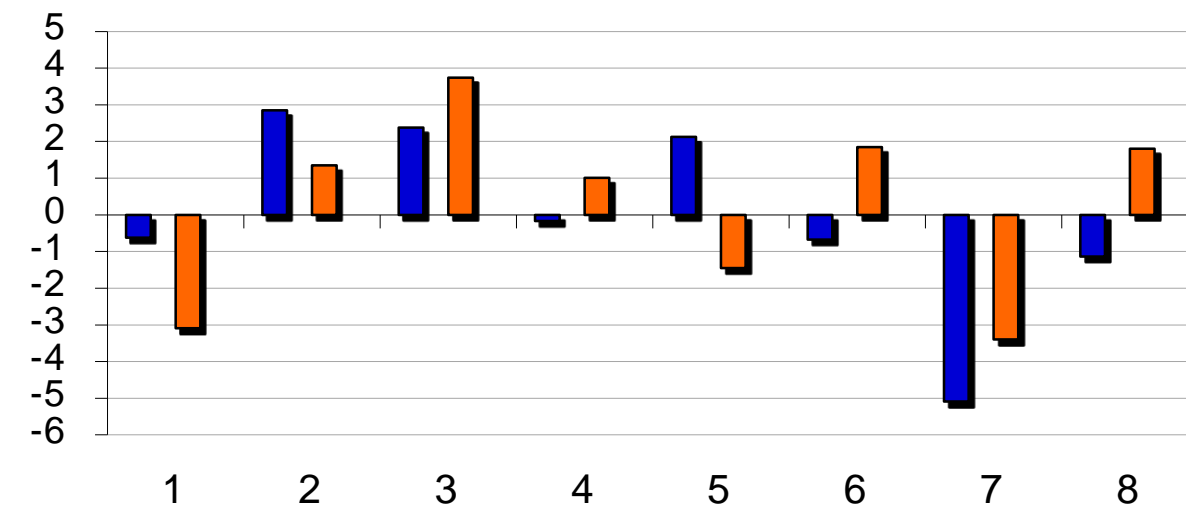


1. Very different size distributions (x axis: \log_{10}) between DC and cirrostratus cloud objects
2. The size distributions are similar for objects smaller than medium sizes for all phases
3. Phases 3-6 show more frequent appearance of the largest cloud objects
4. Divide into small (left of arrows) and large (right of arrows) groups of cloud objects

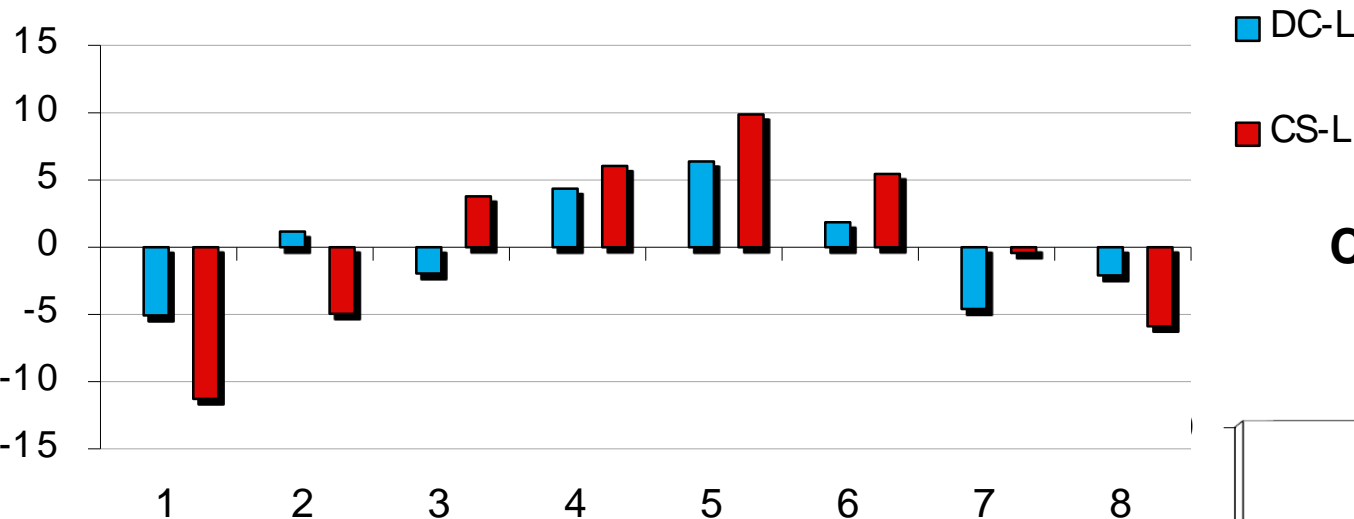
Relative changes (%) in number of objects



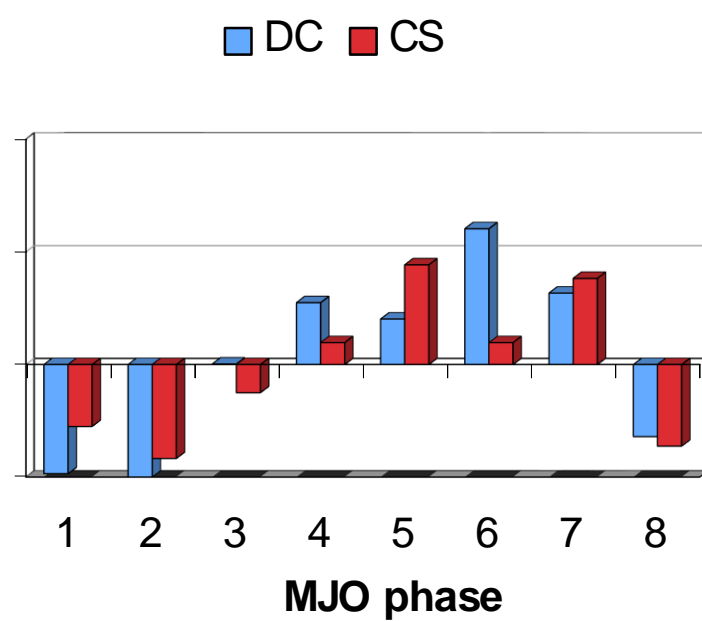
Relative changes in footprint numbers



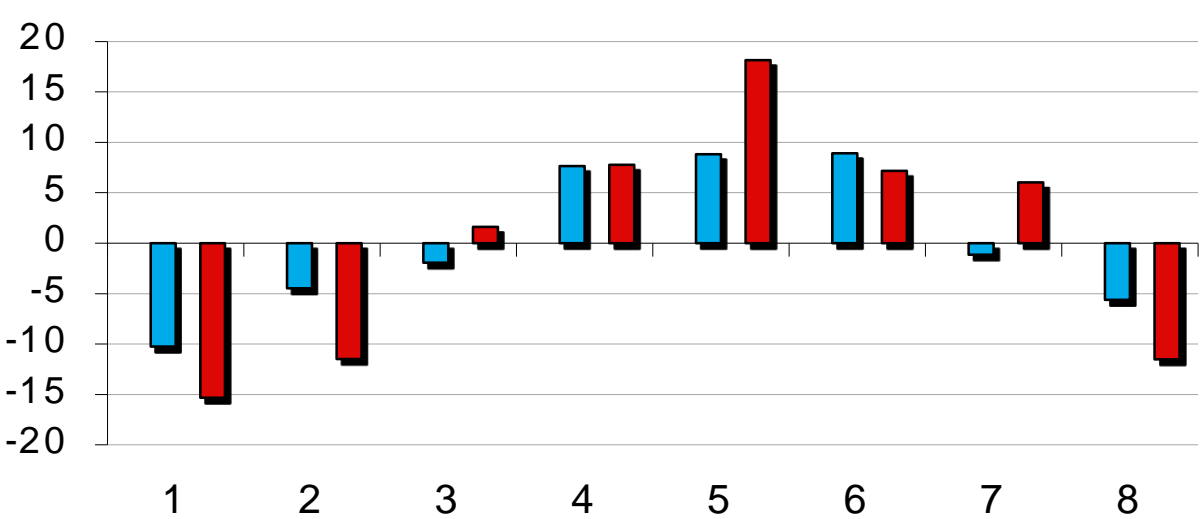
Relative changes (%) in number of objects



Change in Diameter (km)

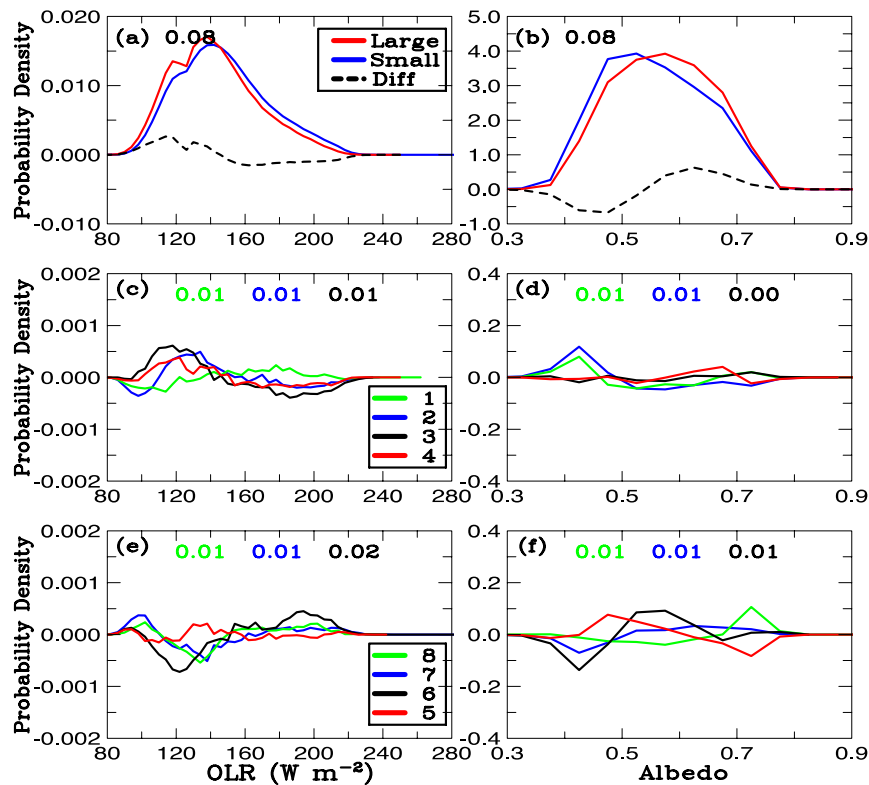


Relative changes in footprint numbers

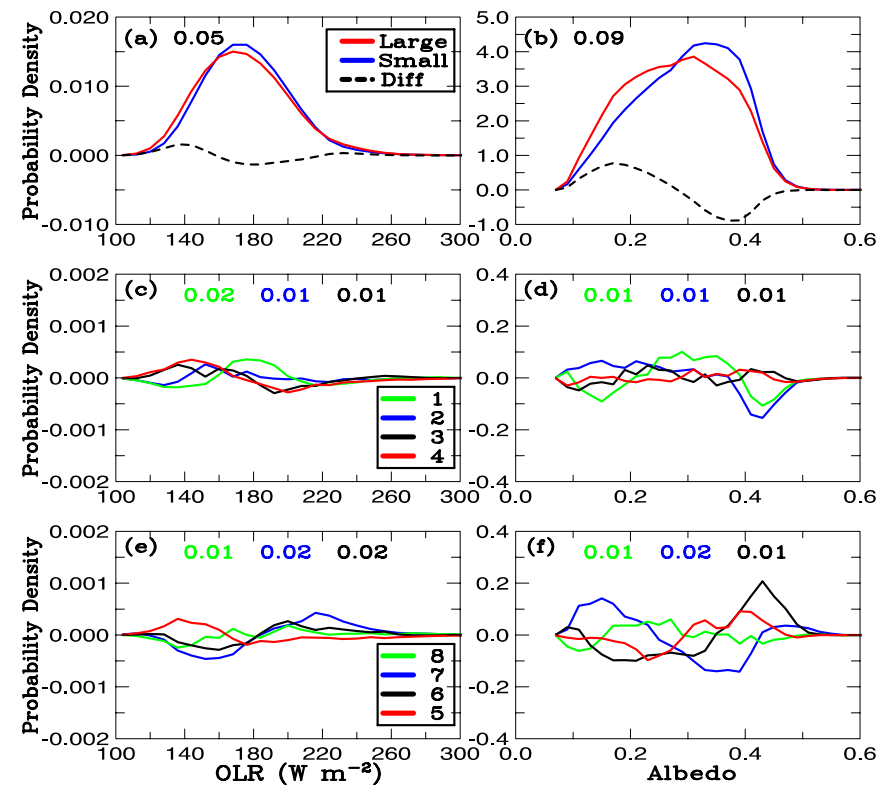


Variations of cloud and radiative properties--all MJO phases¹²

Deep convective



Cirrostratus



Instead of the entire PDFs for each phase, we will show the deviations of PDF from the all-phase PDFs to examine the variations with the MJO phase.

Q: What are the relative roles of small and large convective cloud clusters during the MJO life cycle?

- How are the size distributions of convective cloud clusters changed during the MJO life cycle?
- How much are physical properties changed from one MJO phase to another?

- The contrasts between the suppressed and active phases are not as pronounced as previously thought (MJO schematics); e.g., there is abundant deep convection during the depressed phases in regions outside of Indian Ocean-Maritime Continent.
- There is almost no variation in the size distributions in the small ranges, but large variations in the large ranges, from one MJO phase to another.
- The frequency of occurrence for the large cloud objects changes with MJO phase strongly (magnitudes of $\sim 20\text{-}30\%$); there is a phase lag between deep convective and cirrostratus; increased mean cloud object diameters during the mature phases.
- Although changes in the properties within each cloud type with the MJO phase are relatively small (i.e., compared to all-phase differences between the large and small sizes), those associated with the large-size cloud objects are marginally greater than those of the small-size cloud objects.